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THE USE OF STANDARDIZED INDICATORS (SPI AND SPEI) IN PREDICTING DROUGHTS OVER THE REPUBLIC OF MOLDOVA TERRITORY

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Key words: Standardized Precipitation Index (SPI), The Standardized Precipitation Evapotranspiration Index (SPEI), temporal estimation, spatial analysis.

Abstract The drought events frequent manifestation over the Republic of Moldova territory, in the context of climate change requires a scientific monitoring adjusted to international researchers. In recent years, internationally, the estimation of this phenomenon occurs through standardized indexes. The most used of these, being the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI). Since there is no a unified definition of drought, the World Meteorological Organization proposes to calculate the indexes, through developed calculation software. Thus, based on multi-annual data (1980-2014) a regional spatio-temporal estimation concerning drought in the Republic of Moldova was performed, thereby realizing the regional investigations framing in the international ones.

Introduction

So far, neither around the world nor in Republic of Moldova, there is no a universally accepted terminology regarding the definition of drought, this is the explanation at the section of using wide range of indices to estimate this phenomenon. In this context, the World Meteorological Organization proposes the calculation of Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI) – as the basic indicators in order to quantify the intensity, duration and spatial extent of drought. Thus, the SPI index proposed by McKee et al. [2] and SPEI index elaborated by Serrano, Begueria and Moreno [3] were the basis for drought monitoring in recent decades over the Republic of Moldova territory.

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1. Initial material and research methods

In the recent study have been used monthly data series concerning precipitation and air temperature recorded at 16 stations and 11 precipitation stations of State Hydrometeorological Service of the Republic of Moldova for a period of 35 years (1980-2014).

Soil moisture conditions "respond" to precipitation anomalies on a relatively short time scale. Groundwater, river flow rate and the accumulations in reservoirs, reflects longer-term precipitation anomalies. For these reasons, McKee et al. [2] calculated SPI for different time intervals (3, 6, 12, 24 and 48 months). The software that allows automatic calculation of the index is available on the World Meteorological Organization web page [6]. SPI is a simple index based on the probability of precipitation, and for its calculation are required only data regarding monthly precipitation for a period of at least 30 years. The precipitations are normalized, using a probability distribution, so that the SPI values are in fact, seen as the standard deviations from the median. Positive SPI values characterize wet periods and negative ones - dry periods. SPI distribution for the whole period is normal; the average is equal to zero and the standard deviation - with the unit. The main disadvantage of this index is that it uses only precipitation, without taking into account the thermal regime and evapotranspiration.

Table1. The quantification of the drought distribution probability, according to SPI

SPI	Category	The frequency of in 100 years	The severity of the event
0 – -0.99	Mild Drought	33	1 in 3 years
-1.00 – -1.49	Moderate Drought	10	1 in 10 years
-1.5 to – -1.99	Severe Drought	5	1 in 20 years
< -2.0	Extreme Drought	2.5	1 in 50 years

The SPEI is calculated based on the amount of data that characterize atmospheric precipitation, temperature and latitude of the place, which allows to take into account the potential evapotranspiration. SPEI is based on the water balance, and it can be compared to the Palmer Drought Severity Index (PDSI). SPEI It is based on the original procedure of calculation of index and uses the same SPI available time scales. The SPEI calculation is based on monthly difference between precipitation and potential evapotranspiration, which is a simple methodology of water balance and can be calculated, as well, at different time scales. Therefore, for SPEI calculation, is used a comprehensive set of data characterizing atmospheric precipitation, temperature and the potential evapotranspiration. In this context, it was created special software to automatically

calculate the SPEI, for a wide range of time scales. The software is available for free on the Spanish National Research Council web page [1, 5].

The quantification and the probability drought distribution (the example of SPI) are presented in Table 1.

2. Analysis of the results

Therefore, at regional level for the first time, automatic calculation of above mentioned indexes has took place, which has helped to essential improve researches in this area. Thus, for the last decades (1981-2014), it was carried out a scientific monitoring of droughts: duration, intensity and the area of manifestation in the Republic of Moldova.

Table 2. Data from the SPI-SPEI Database, Chisinau station

Years	Months	SPI 1	SPI 3	SPI 6	SPI 12	SPEI 1	SPEI 3	SPEI 6	SPEI 12
1980	1	-0.37	0.00	0.00	0.00	-0.4828	0.0000	0.0000	0.0000
1980	2	-1.18	0.00	0.00	0.00	-0.9399	0.0000	0.0000	0.0000
1980	3	1.38	0.12	0.00	0.00	1.6410	0.3800	0.0000	0.0000
1980	4	0.43	0.54	0.00	0.00	0.7246	1.0022	0.0000	0.0000
1980	5	0.44	0.93	0.00	0.00	0.8954	1.4062	0.0000	0.0000
1980	6	1.16	1.00	0.85	0.00	1.3322	1.4147	1.3123	0.0000
1980	7	0.46	1.00	1.07	0.00	0.6782	1.5508	1.5192	0.0000
1980	8	1.23	1.37	1.60	0.00	1.4520	1.6931	1.8771	0.0000
1980	9	-0.45	0.55	1.03	0.00	-0.1575	1.0377	1.6469	0.0000
1980	10	-0.03	0.35	0.95	0.00	0.0259	0.7971	1.5412	0.0000
1980	11	1.49	0.43	1.38	0.00	1.5427	0.5942	1.7595	0.0000
1980	12	0.86	1.15	1.09	1.46	0.9051	1.2371	1.4795	1.8661
1981	1	0.87	1.81	1.25	1.74	0.9274	2.0790	1.4856	2.0064
1981	2	0.32	0.99	0.85	1.86	0.2715	1.0540	1.0082	2.0633
1981	3	0.18	0.56	1.23	1.58	0.1528	0.5100	1.2946	1.7804
1981	4	-0.13	-0.01	1.31	1.45	0.4962	0.4356	1.5170	1.7218
1981	5	-0.34	-0.38	0.33	1.33	-0.0166	0.2562	0.7016	1.6770
1981	6	-1.33	-1.16	-0.62	0.49	-1.3568	-0.6469	-0.2485	0.9837
1981	7	-0.83	-1.75	-1.49	0.04	-0.7400	-1.1435	-0.7497	0.5037
1981	8	-0.38	-1.71	-1.66	-0.63	0.0546	-1.1518	-0.7833	-0.1365
1981	9	0.65	-0.49	-1.29	-0.14	0.6666	-0.2847	-0.6560	0.0624
1981	10	0.30	0.13	-1.23	-0.07	0.0869	0.2674	-0.8254	0.1060
1981	11	1.83	1.28	-0.11	0.10	1.8502	1.2378	-0.0777	0.3045
1981	12	0.53	1.34	0.52	-0.07	0.5069	1.3682	0.7409	0.2903

First of all, an enormous Data Base was developed concerning SPI and SPEI values in the period 1981-2014 for 16 stations and 11 precipitation stations of the State Hydrometeorological Service, at 4 time scales: 1 month, 3 months, 6 months and 12 months (SPI 1, SPI 3, SPI 6, SPI 12, SPEI 1, SPEI 3, SPI 6, SPI 12). The information presented in Table 2 reflects a fragment of information databases developed for Chisinau station.

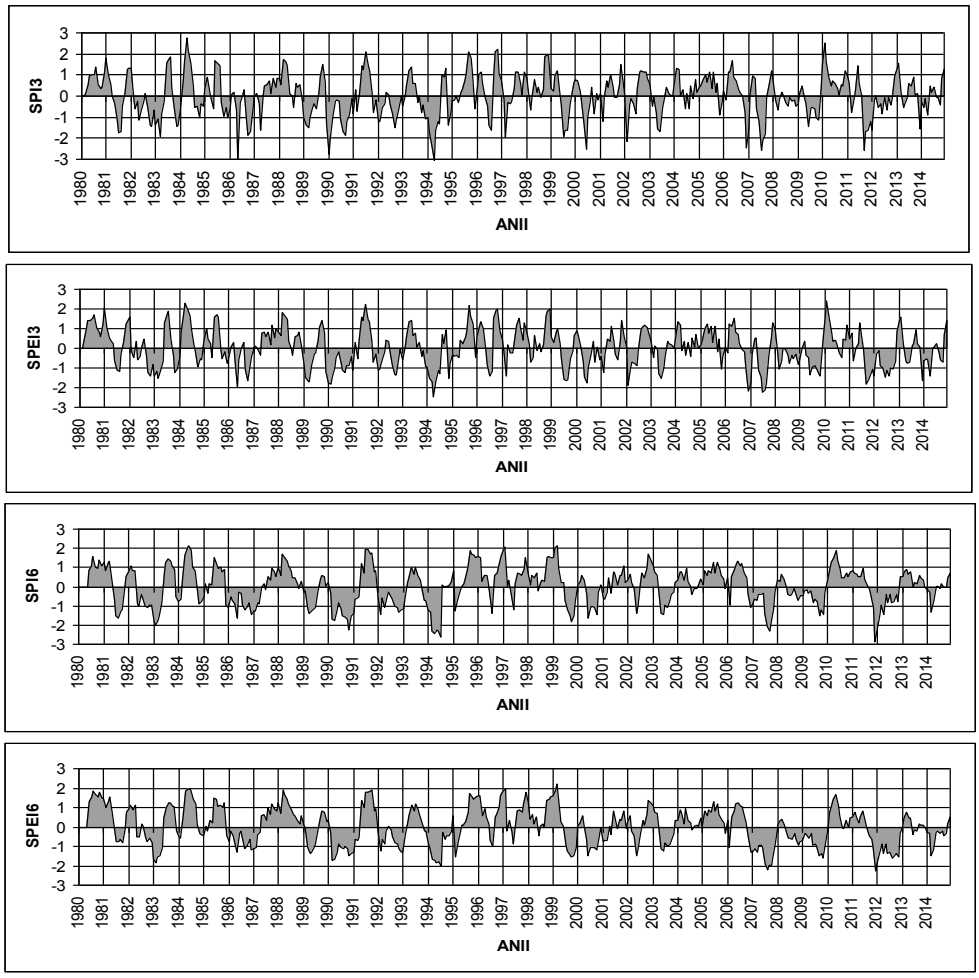

Fig.1. The SPI and SPEI time series (for3 and 6 months), Chişinău station, Republic of Moldova

The developed Database allows the estimation of temporal drought, highlighting not only the intensity of the phenomenon, but also the duration of manifestation in time. So the SPI index values of a time scales (ex.1 month) *n* compares the amount of precipitation of the time scales (SPI-1) and *n-1* months to average amount of rainfall during the investigated period for the same period. In the case of SPEI the water balance is compared.

So, have been elaborated graphs representing SPI values, SPEIA the evolutionary aspect, depending on the year, season and month during 1981-2014. For example, the charts are shown for a scale of 3 and 6 months for the central part of the country (Chisinau).

SPI and SPEI graphs that are shown in Figure 1, being on the same time scale, they have very similar shapes, but the duration and intensity differs as SPEI takes into account not only the amount of precipitation, but also the evapotranspiration (Fig.1). At the same time, the calculation of these indexes for longer time scales (6 months) allows highlighting the scale of the phenomenon over time and therefore to argue consequences incurred as a result of an extended drought event.

These investigations allowed the elaboration of Drought Register (Tab.3) according to SPEI 3 and 6 SPEI values (for example data on Chisinau station), which allows monitoring this phenomenon in temporal aspect. Such results are extremely important for the evaluations that have a character of prediction. Therefore, the SPEI average value for a time interval with continuous values ≤ -1, multiplied by duration in months of this interval (expressed in months), is the "surface" of the chart for values ≤ -1. In the table 3 there are shown the intervals with values of this product ≤ -5, corresponding to severe droughts that lasted long.

Table 3. The Droughts Register developed based on SPI-SPEI indexes for different time scales (Chisinau station, Republic of Moldova)

Index	The beginning	The end	The duration, months	The maximum intensity of drought	Mean value	Mean value *duration
SPEI3	07.1981	08.1981	2	-1,1518	-1,1476	-2,2952
	10.1982	11.1982	2	-1,3989	-1,3057	-2,6114
	01.1983	04.1983	4	-1,5034	-1,3059	-5,2236
	11.1983	12.1983	2	-1,2067	-1,1473	-2,2946
	05.1986	05.1986	1	-1,9877	-1,9877	-1,9877
	09.1986	11.1986	3	-1,6565	-1,3219	-3,9657
	02.1989	04.1989	3	-1,6903	-1,5966	-4,7898
	01.1990	03.1990	3	-1,8230	-1,7017	-5,1051
	08.1990	09.1990	2	-1,2440	-1,1819	-2,3638
	01.1991	01.1991	1	-1,1159	-1,1159	-1,1159
	01.1992	02.1992	2	-1,1358	-1,0857	-2,1714
	09.1992	10.1992	2	-1,3783	-1,3529	-2,7058
	02.1994	07.1994	6	-2,4844	-1,6257	-9,7542
	11.1994	11.1994	1	-1,5469	-1,5469	-1,5469

	The beginning	The end	The duration, months	The maximum intensity of drought	Mean value	Mean value *duration
	07.1996	08.1996	2	-1,3949	-12948	-2,5896
	03.1997	03.1997	1	-1,3892	-1,3892	-1,3892
	07.1999	09.1999	3	-1,6523	-1,6110	-4,8340
	05.2000	06.2000	2	-1,7777	-1,6303	-3,2606
	02.2001	02.2001	1	-1,2070	-1,2070	-1,2070
	02.2002	03.2002	2	-1,8935	-1,4569	-2,9138
	05.2003	06.2003	2	-1,5272	-1,4220	-2,8440
	11.2005	11.2005	1	-1,0533	-1,0533	-1,0533
	11.2006	01.2007	3	-2,1741	-1,6592	-4,9776
	05.2007	09.2007	5	-2,2445	-1,7510	-8,7550
	06.2009	06.2009	1	-1,3390	-1,3390	-1,3390
	09.2009	11.2009	3	-1,4251	-1,2559	-3,7677
	09.2011	01.2012	5	-1,8093	-1,4532	-7,2660
	06.2012	08.2012	3	-1,4867	-1,3267	-3,9801
	10.2012	10.2012	1	-1,0687	-1,0687	-1,0687
	04.2014	04.2014	1	-1,3850	-1,3850	-1,3850
SPEI6	01.1983	05.1983	5	-1,8649	-1,5248	-7,6240
	05.1986	05.1986	1	-1,3209	-1,3209	-1,3209
	09.1986	09.1986	1	-1,1168	-1,1168	-1,1168
	12.1986	02.1987	3	-1,1852	-1,1189	-3,3567
	03.1989	06.1989	4	-1,3777	-1,1932	-4,7728
	03.1990	05.1990	3	-1,7031	-1,5433	-4,6299
	07.1990	01.1991	7	-1,4857	-1,2019	-8,4133
	02.1992	02.1992	1	-1,2541	-1,2541	-1,2541
	11.1992	01.1993	3	-1,2997	-1,2324	-3,6972
	02.1994	07.1994	6	-2,0279	-1,6854	-10,1124
	02.1995	02.1995	1	-1,5629	-1,5629	-1,5629
	08.1996	08.1996	1	-1,0024	-1,0024	-1,0024
	08.1999	12.1999	5	-1,5546	-1,3455	-6,7275
	06.2000	10.2000	5	-1,5099	-1,1667	-5,8335
	05.2002	06.2002	2	-1,4797	-1,3457	-2,6914
	05.2003	06.2003	2	-1,2541	-1,1923	-2,3846
	08.2003	08.2003	1	-1,0007	-1,0007	-1,0007
	02.2006	02.2006	1	-1,0838	-1,0838	-1,0838
	12.2006	03.2007	4	-1,3093	-1,2435	-4,9740
	06.2007	11.2007	6	-2,1986	-1,7718	-10,6308
	09.2009	11.2009	3	-1,5804	-1,4812	-4,4436
	11.2011	02.2012	4	-2,2926	-1,6525	-6,6100
	04.2012	04.2012	1	-1,3839	-1,3839	-1,3839
	06,2012	11.2012	6	-1,5784	-1,4499	-8,6994
	03.2014	04.2014	2	-1,5118	-1,3438	-2,6876

However, besides time manifestation of this adverse climatic event, it is extremely important to know and its distribution areas, in order to perform accurate recovery measures if dangerous situations.

In this context, it is necessary to develop digital maps that reflect the spatial distribution of SPI and SPEI values for each concrete month, season and year, when the manifestation and duration of droughts was pronounced and intense. We

note that the proposed achievements in this work, have allowed developing a set of digital maps, providing full scientific monitoring of droughts in recent decades at different time scales.

a b

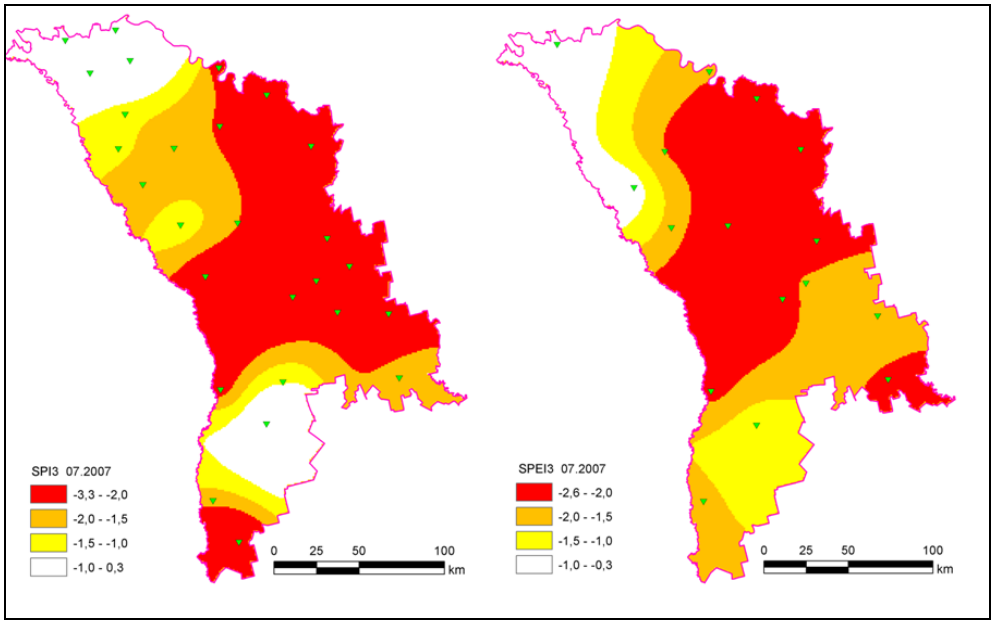

Fig.2. The spatial distribution of the SPI-a and SPEI-b indexes in July 2007 (time scale - 3 months)

So, according to SPI (fig.2a), in July 2007, the drought calculated for 3 months time scale (May, June, July), had a severe manifestation in the extreme south, central and east of the country, where rainfall amount in this period was lower than even in Comrat (June 4, in Comrat fell the monthly norm of precipitation of 79 mm). The map (fig.2b) that reflects the spatial distribution of SPEI in July 2007, calculated on the same time scale, indicates that the severity of this phenomenon is experienced in central-east and south-east, where the thermal regime and evapotranspiration was high on the background of small quantities of atmospheric precipitation.

Spatial distribution of SPEI and SPI values for the same month (July 2007), but the time scale calculated for 6 months (February, March, April, May, June, July) reports that under SPI 6, extreme drought was manifested in the extreme south of the country, north-east and Dubăsari, where atmospheric precipitation of this month lead the emergence of this situation (Fig. 3a). In the case of SPEI values (Fig. 3b) for the same scale of time (6 months), it "expands" the area of severe

drought in July, largely explained by uninterrupted period of high temperature and high evapotranspiration, also on the background of reduced precipitation in the months preceding (February, March, April, May, June, July).

a b

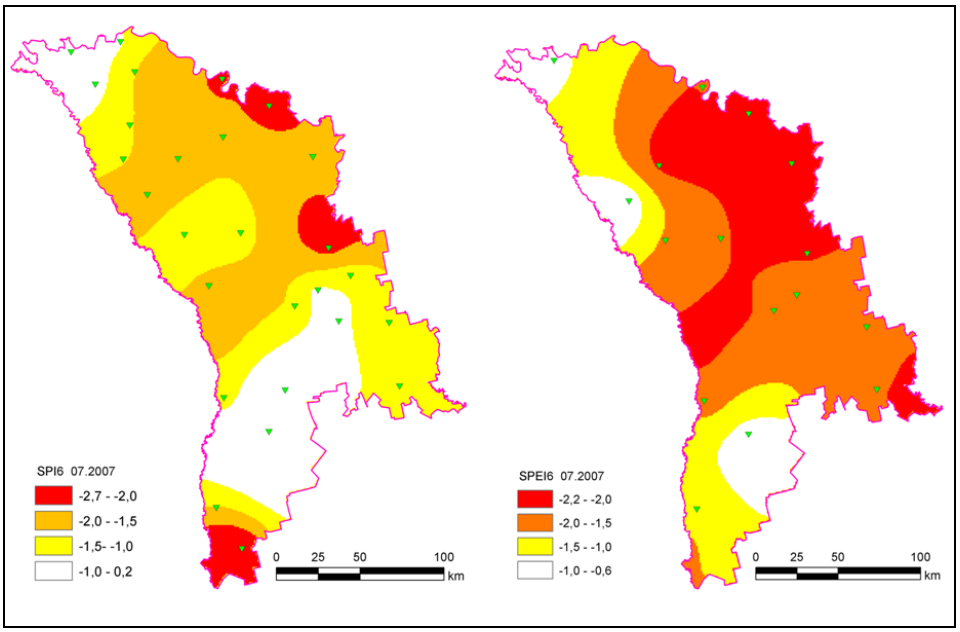

Fig.3. Spatial distribution SPEI and SPI in July 2007 (time scale - 6 months)

Conclusions

In conclusion we find that, besides the fact that such researches contribute to alignment of regional towards international research, the results contribute to the proper scientific monitoring of drought over the Republic of Moldova, thus emphasizing not only the severe character of the event, but also preceding periods for this phenomenon - knowledge extremely important for farming practices. The presented digital maps will serve as reference in drafting the Atlas concerning to scientific monitoring of droughts over the Republic of Moldovan territory.

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